3.2. Basic System Characteristic Comparisons

	System A		System B	Expression Used
Length of Burst, Tp, comparison		96:1[3]		(8) (equal SNRo)
Length of Burst, Tp, comparison		1:1[4]		(8A) (equal Pr)
Capacity Comparison		1:13[5]		
Processing Gain	39dB		24dB	(
Jamming Margin, JM	23dB		14dB	(11)
Near-Far Ratio	4.53		2.52	(14)
Near-Far Ratio,NFR, comparison		1.8:1		(15)
Occupied Bandwidth	4MHz		8MHz	
Range comparison		2.19:1		(13)

4. DISCUSSION

4.1. Capacity

The best comparison between the systems is to use expression (8A') but because of the 150ms overhead required by the Quiktrak system it is difficult to directly compare without using actual values. It is necessary therefore to calculate the theoretical length of the location burst, for a practical set of conditions.

Using (8'), assuming R = 10ns, Tp' = 1.53 + .15 = 1.68secs[6]. This is the theoretical length of a location burst to give a timing jitter of 10ns with an output SNR of 16dB. Assuming 4 channels, this would give a total maximum capacity, for system A, of 8570 locations per hour.

The same calculation for system B gives Tp = 31.9ms. This is equivalent to a maximum capacity of 112,950 locations per hour.

Thus the theoretical comparison for capacity is 13:1 in favor of system B. Taking the difference in chipping rate into account, system B would still have a 3:1 advantage[7].

From this comparison it can be seen that the fundamental capacity of a Quiktrak type system is significantly less than that of a MobileVision type system.

The poorer capacity, as shown in the comparison chart, is due partly to the slower chipping rate. SBMS is contending that the spectrum should be split into 4 bands of 4MHz each, so that it complies with the system that it is obtaining from Australia. The calculated comparisons show that there would be a dramatic loss of capacity overall if this was carried out.

4.2. Jamming Margin

The Quiktrak system has a 9dB improvement in JM over the MobileVision system due to the extra integration time required to filter the individual channels. SBMS claims a 15dB improvement over MobileVision but that probably assumed an equal output SNR requirement. It has been derived that the Quiktrak system requires 16dB as against 10dB for MobileVision.

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[3]not including the 150ms overhead as given in (8') and (8A').
[4]not including the 150ms overhead as given in (8') and (8A').
[5]This is shown calculated in section 4.1 below.
[6]SBMS have stated that they use a standard 1112ms location burst.
[7]The original Quiktrak system at 420MHz had 12 channels but at 920MHz only 5 channels are possible. Thus, the higher the operating frequency, the less efficient the Quiktrak system becomes.

The good JM figure for Quiktrak does make it a robust system against interference. If we compare the Near-Far Ratios then we find that the NFR is less than twice that of a MobileVision type system. This demonstrates that the effect of the good JM is not that dramatic in practice because the Jamming margin is reduced by the power of 3.5, due to the propagation loss due to distance.Larger area clusters will tend to reduce any advantage gained through a higher near-far ratio.

4.3. Range

Because of the improved PG, the range of the Quiktrak system is better than that of a MobileVision type system. This is a positive advantage as a particular area can be covered by fewer sites. Given the poorer capacity of the system, however, it is debatable as to whether it would be advisable to utilize this range advantage. Larger areas will have more mobiles in them, and thus will require more capacity.

5. CONCLUSIONS

The Quiktrak system, which SBMS propose to use, has a novel approach in that it uses multiple frequency channels. This results in improved PG and hence JM and range. Unfortunately, in adapting the system from one designed at 420MHz to work at 920MHz, the improvements are reduced in that the original system had 12 channels and the adapted system 5 channels. The fundamental capacity of the system is significantly less than a MobileVision type system. The practical effect of the improved JM is not so apparent when one considers the near-far ratio especially with respect to larger cluster sizes.

The occupied bandwidth is 4MHz and SBMS have proposed that 4 bands of 4MHz be adopted for LMS. This would cause a significant overall reduction in the capacity offered in any one of these bands and that the overall capacity, compared to that offered by two 8MHz bands would also be reduced significantly because the capacity is related to the square, or cube, of the bandwidth.

The conclusion is that the Quiktrak system, although having better range and jamming margin than a MobileVision type system, has fundamentally less capacity and is much more complex. The only advantage of the Quiktrak system is that the JM is good and hence it is a more robust system.

ANNEX 3
INTERFERENCE ANALYSIS OF LOCAL AREA AND WIDE BAND SYSTEMS

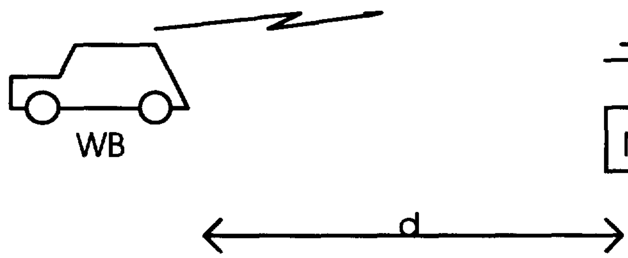
1. INTRODUCTION

There are 8 mechanisms for interference when two separate systems share the same frequency band. These are:

1 - Wide band mobile transmission blocking Local area fixed reception.
2 - Wide band mobile transmission blocking Local area mobile reception.
3 - Wide band fixed transmission blocking Local area fixed reception.
4 - Wide band fixed transmission blocking Local area mobile reception.
5 - Local area fixed transmission blocking Wide band fixed reception.
6 - Local area fixed transmission blocking Wide band mobile reception.
7 - Local area mobile transmission blocking Wide band fixed reception.
8 - Local area mobile transmission blocking Wide band mobile reception.

2. CALCULATIONS

2.1 - Wide band mobile transmission blocking Local area fixed reception.



In this case the two antennas are close to the ground therefore plane earth propagation is assumed. The plane earth propagation loss is given by the formula[1]:

$$Lp = 147.5 - 20 \log h1\ h2 + 40 \log d$$

where h1, h2 are antenna height in feet and d is the distance in miles.

Assuming h1 = 30 and h2 = 6

$$Lp = 102.4 + 40 \log d$$

Assuming that the Wide area mobile transmits at 40W, the received level at the Local area receiver will be:

$$Pr' = 46 - 102.4 - 40 \log d \quad \text{dBm}$$

Now the Local area receiver bandwidth is believed to be about 1MHz, so, assuming the mobile spread spectrum is 4 MHz wide (2MHz chipping frequency) the effective received signal will be 6dB less.

Therefore $\quad Pr = Pr' - 6 = -62.4 - 40 \log d \quad \text{dBm}$

Assuming the received level is between -20 and -30dBm [2]and a signal to noise ratio of 10 dB is required, then the interfering level will need to be -30 to -40dBm in order to desensitize the reception.

---

[1]K.Bullington, "Radio propagation for vehicular communications", IEEE Trans. Veh. Technol., Vol. VT-26, no. 4. pp 295-308, Nov. 1977.

Thus, for -20dBm- $\quad -62.4 - 40 \log d = -30$

$$40 \log d = -32.4$$

$$\underline{d = .155 \text{ miles } (818 \text{ feet})}$$

and for -30dBm- $\quad -62.4 - 40 \log d = -40$

$$40 \log d = -22.4$$

$$\underline{d = .275 \text{ miles } (1450\text{feet})}$$

The above calculations have assumed that the receiving antenna does not have any gain in the direction of the interfering signal. This is not necessarily true and any antenna gain would amplify the interference.

The results show that there certainly is a potential interference and that a mobile within 1000feet of the local area system definitely has the ability to interfere.

If the local area fixed transmission power is reduced to 200 or 50 mW, in order to reduce the interference to the wide band fixed receiver (discussed in 2.5 below), as has been suggested, then the interference level [redacted]

$$Lp = 117 + 20 \log f - 20 \log h1\ h2 + 40 \log d$$

where the frequency is f MHz
h1 and h2 are the antenna heights, in feet
and d is the distance in miles.

For h1 = 300, h2 = 30 and f = 920

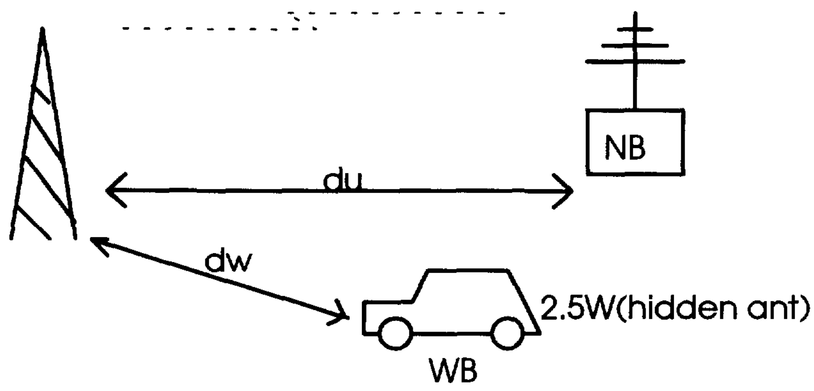
$$Lp = 94.9 + 40 \log d$$

Assuming the transmitted power from the fixed tower is 5000W, as proposed by Pinpoint, then the received level will be:

$$Pr = 67 - 94.9 - 40 \log d \text{dBm}$$
$$Pr = -27.9 - 40 \log d$$

Assuming the same interfering levels as in 2.1., i.e. -30 and -40 dBm

2.5- Local area fixed transmission blocking Wide band fixed reception



It is assumed that the wide band mobile transmission is 2.5W (34 dBm). This corresponds to the case of a 10W mobile transmitter and a hidden antenna (-6dBi).

Assuming a jamming margin of JM dB and a transmission power of Pt dBm from the local area transmitter, using the 'Egli' propagation formula, the wanted received signal will be:

$$Pw = 34 - 114.7 - 20 \log f + 20 \log h1\ h2 - 40 \log dw + JM$$

For h1 = 300, h2 = 6, f = 920

$$Pw = -74.9 + JM - 40 \log dw$$

As per the 2.3, the unwanted received signal will be:

$$Pu = Pt - 94.9 - 40 \log du$$

Blocking occurs when Pw = Pu.

The value of Pt can vary with the directivity of the local area system antenna. A value of 30W ERP seems to be the most favored power suggested, but it has also been suggested that the power could be reduced to 200mW or 50mW. As a directional antenna is used at the local area site, the power transmitted in the direction of the wide band fixed site could be, say, 10dB down.

The following table shows the calculated ratios of dw/du against different values of JM and Pt.

Local area fixed transmission blocking Wide band fixed reception

Wide band mobile transmitted power = 2.5W(34dBm)
Local Area fixed transmission power = Pt dBm

Pt =	30W	3W	200mW	50mW	20mW	5mW
Pt dBm=	45	35	23	17	13	7
JM dB	**dw/du**	**dw/du**	**dw/du**	**dw/du**	**dw/du**	**dw/du**
5	0.32	0.56	1.12	1.58	2.00	2.82
14	0.53	0.94	1.88	2.66	3.35	4.73
20	0.75	1.33	2.66	3.76	4.73	6.68

dw = distance of WB mobile from the WB fixed site.
du = distance of the local area system from the WB fixed site.

These results show that the interference is very real. To put them in a more readable manner, let us take the case of the mobile being 5 miles from its fixed site. The required distance that the local area system must be sited away from the wide band fixed site is then as shown below:

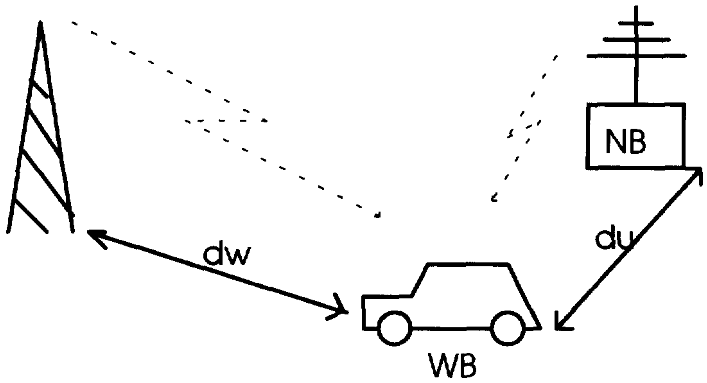
Required distance of Local Area system from WB fixed site
Assuming WB mobile is 5 miles from WB fixed site.

Wide band mobile transmitted power = 2.5W(34dBm)
Local Area fixed transmission power = Pt dBm

Pt =	30W	3W	200mW	50mW	20mW	5mW
Pt dBm=	45	35	23	17	13	7
JM dB	**d miles**	**d miles**	**d miles**	**d miles**	**d miles**	**d miles**
5	15.81	8.89	4.46	3.15	2.51	1.77
14	9.42	5.30	2.65	1.88	1.49	1.06
20	6.67	3.75	1.88	1.33	1.06	0.75

Assuming that the local area system can be sited such that the antenna is pointing away from the wide band fixed site, and the power transmitted reduced to 50mW (assumed 5mW in the direction of the WB fixed site), then the local area system must be at least a mile away. It should be noted that the jamming margin of the wide band system has an effect, and that a system with a lower jamming margin will be definitely more susceptable to blocking.

2.6 - Local area fixed transmission blocking Wide band mobile reception.



Assuming that the wide band fixed transmitter power is 500W;

Using 'Egli', at the mobile, Pw = 57 - 108.9 - 40 log dw
Pw = -51.9 - 40 log dw

Assuming 30W from the local area fixed transmitter, and plane earth propagation;
Pu = 45 - 102.4 - 40 log du
Pu = -57.4 - 40 log du

Assuming a 10dB S/N required, log dw/du = -4.5/40 dw/du =0.77

i.e. if the mobilemust be closer to the WB fixed site than it is to the local area system.

Assuming 3 W from the local area fixed transmitter (to account for directivity of the antenna),

log dw/du = 5.5/40 dw/du = 1.37

i.e. if the mobile is 5 miles away from the fixed site, then it must be 3.6 miles away from a local area system to avoid interference.

This particular interference can be avoided if the local area transmitter is not on the same frequency as the wide band system forward link (which is usually narrow band).

2.7 - Local area mobile transmission blocking Wide band fixed reception.
2.8 - Local area mobile transmission blocking Wide band mobile reception.

Using the 'Free Space Propagation' loss formula, the loss of a 920MHz signal over 10 feet is 40dB. Therefore the local area mobile re-transmission is in the order of 40dB down on the local area fixed site power. This power is spread over about 1MHz bandwidth. Therefore the interfering signal, to the wide band system, is in the order of 40dB and 56dB less than that of the local area fixed transmitter to the wide band fixed receiver and mobile receiver respectively.

3. DISCUSSION OF RESULTS

3.1 Desensitizaton of the local area system by the wide area system.

From the calculations carried out in 2.1. it can be seen that a definite cause of interference is the wide band mobile transmission blocking the local area fixed receiver. If the mobile is within 1000 ft of the local area system then there exists a real possibility of interference. If the local area system was sited at a toll booth then, in rush hour scenarios, it would be quite possible that several mobiles will be in the area, therefore it would be naive to ignore this possible interference. The suggestion that the local area transmitter power should be reduced, from 30W to 200 or 50 mW, so as to lower the possible interference to the wide band system, would result in any mobile within a mile of the local area system being capable of blocking it.

The wide band forward link is also cable of blocking the local area receiver. If Pinpoints's suggested power of 5000W was accepted then the local area system would need to be in the order of 2 miles away, even if it was using 30W power. This reduces to 1 mile if only 500W is transmitted. If the power levels used at the local area site are reduced to 200 or 50mW, then the local area system must be over 4 miles away. Considering that the received signal from the passive tags is in the order of being 1MHz wide, this form of interference must represent a real threat to teh local area systems.

3.2. Desensitization of the wide band system by the local area system.

The calculations given in 2.5. and 2.6. show that both the wide band system's fixed site receiver and mobile receiver are subject to interference from the local area system transmitter. The tables given in 2.5. show the relationship between the effective transmitted power, the jamming margin and the distances required to avoid interference. Unless there is extremely careful planning of the location of the respective sites, it is inevitable that interference will occur. In the case where a bank of local area transmitters are used, at multi-lane toll booths, for example, this interference will worse.

The calculations in 2.6. show that the mobile reception could be blocked by the local area transmitter. Assuming that the two transmissions are both narrow band, then the effect would be to effectively block these channels and it would probably be possible to arrange that the two do not coincide. If the wide band system forward link is itself wide band, then this interference would be very real.

4. CONCLUSION

The calculations show clearly that there is significant interference between the wide band and local area systems. *The calculations, given in 2.1. and 2.5. especially, represent the clearest evidence that the two systems cannot share the same frequency band.*

ANNEX 4

INTERFERENCE ANALYSIS OF WIDE BAND SYSTEMS SHARING SAME FREQUENCY BAND

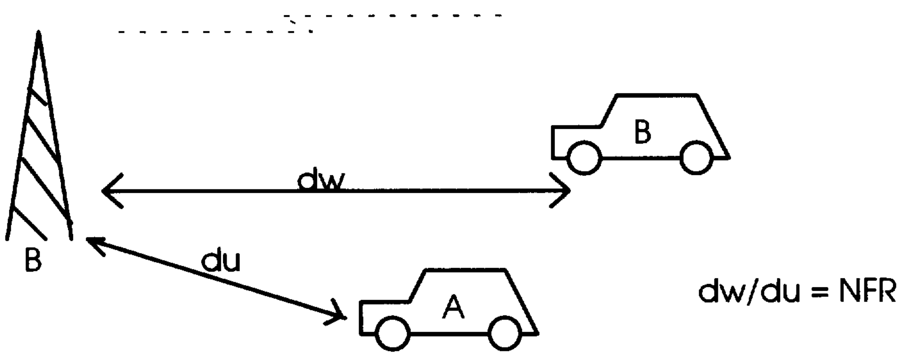
1. INTRODUCTION

Assuming that two wide band systems, A and B, are sharing the same frequency band, the following interference mechanisms exist:

1 - System A mobile transmission blocking system B fixed site reception.
2 - System A mobile transmission blocking system B mobile reception.
3 - System A fixed site transmission blocking system B fixed site reception.
4 - System A fixed site transmission blocking system B mobile reception.

2. CALCULATIONS

2.1. System A mobile transmission blocking system B fixed site reception.



In the Hata formula[1] the propagation loss due to distance is:

$(44.9 - 6.55 \log h_b) \log D$ where h_b is the base station antenna height (m) and D is the distance (kms.)

Thus for a 100ft (30m) mast, the loss is 35.22 log D and therefore, the propagation loss, due to distance, is $R^{3.5}$.

Thus an interfering signal source located one mile from the receiving site will be received about 11 ($2^{3.5}$) times stronger than a desired signal located two miles from the receiving site i.e. 10.5dB higher

A spread spectrum signal has what is known as a "Jamming Margin"[2]. This is the residual advantage that the system has against a jammer and/or noise. Assuming zero system loss, this can be defined as:

Jamming Margin, JM = PG - (SNR_o) (in dBs) where PG is the processing gain and SNR_o is the output signal to noise ratio

The Processing Gain (PG) is the ratio of the signal bandwidth to the message bandwidth. For direct sequence spread spectrum systems used for location, where correlation of every code sequence is required, the PG is 10.logL dB, where L is the length of the spreading code[3].

An interfering signal, can be up to JM dBs higher than the wanted signal and the wanted signal still be successfully received.

i.e. JM = Pr/Prj where Prj is the power of the received jamming signal and Pr is the power of the wanted received signal. (1)

Assuming the transmitted power of both signals, wanted and unwanted, are the same, then the received signal strengths are related to the distance by $(1/D)^{3.5}$

Hence
$$JM = \frac{dw^{3.5}}{du^{3.5}} \qquad (2)$$

where du is distance of the wanted transmitter (B) and dw is the distance of the unwanted transmitter (A)

Therefore
$$\frac{dw}{du} = \sqrt[3.5]{JM} = NFR \quad \text{(this is known as the Near-Far Ratio)} \qquad (3)$$

The following table shows the resulting near-far ratio, NFR, for various jamming margins, JM.

JM dB	**NFR**	**du miles (for Dw = 5 miles)**
23	4.5	1.11
20	3.73	1.34
14	2.51	1.99
8	1.69	2.95
5	1.39	3.6

Thus for a jamming margin of 14 dB, the near far ratio (dw/du) is 1.99. This means that if the wanted signal is 5 miles away from the receiving site then any unwanted in-band transmission within 1.99 miles of the receiving site will jam the wanted signal.

In the case of Pinpoint the actual PG is only 5dB(because 2 data bits are encoded into each 63 chip sequence). This results in a near-far ratio of only 1.39. If the wanted mobile is 2.8 miles away, then any unwanted mobile within 2 miles of the site will block it.

---

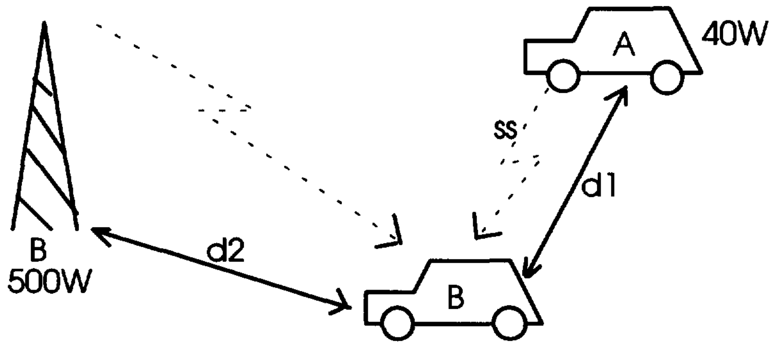
[2]See also Annex 1, section 2.2, for a fuller explanation.
[3]The Quiktrak system requires a long integration time which gives the system a higher PG. Please see Annex 2 for fuller explanation.

A system with a good jamming margin also has a good range. The greater the distance between the sites the higher the possibility of jamming.

It should be remembered that in a spread spectrum location system, it is desirable to be received at as many sites as possible. Therefore it is apparent that several sites will be at a significant distance from the wanted transmission. This will exaggerate the problem.

It should also be noted that the effective power of the unwanted signal is that power within the bandwidth of the spread spectrum receiver. Therefore the above applies to narrow band and spread spectrum interferers alike.

2.2. System A mobile transmission blocking system B mobile reception.



To calculate the level of the interfering level, the received signal at mobile B from a transmission from mobile A, 'plane earth propagation' is assumed. The plane earth propagation loss is given by the formula:

$$Lp = 147.5 - 20 \log h1\ h2 + 40 \log d1$$

where h1, h2 are antenna height in feet and d1 is the distance in miles between the mobiles

Assuming h1 = h2 = 6

$$Lp = 116.4 + 40 \log d1$$

Assuming that mobile A transmits at 40W, the received level at mobile B will be:

$$Pr' = 56 - 116.4 - 40 \log d1 \quad \text{dBm}$$

$$Pr' = -60.4 - 40 \log d1$$

The propagation loss of the wanted signal, using the Egli formula, is:

$$Lp = 114.7 + 20 \log f - 20 \log h1\ h2 + 40 \log d2$$

where the frequency is f MHz
h1 and h2 are the antenna heights, in feet
and d2 is the distance in miles between the mobile and the fixed site..

For h1 = 300, h2 = 6 and f = 920

$$Lp = 108.9 + 40 \log d2$$

Assuming the transmitted power from the fixed tower is 500W, then the received level will be:

$$Pr = 57 - 108.9 - 40 \log d2 \qquad \text{dBm}$$
$$Pr = -51.9 - 40 \log d2$$

a) Assuming that the transmission from the fixed site B is narrow band, say 25 kHz, and that it is situated in the main lobe of the spread spectrum, say 4 MHz, from the mobile A, then the effective interfering level will be reduced by the ratio of 25/4000 (22dB).

Thus the effective interfering signal, $Pr'' = Pr' - 10 \log 4000/25 = -60.4 - 22 - 40 \log d1$

Assuming a required SNR of 10dB, $\qquad Pr'' = Pr - 10$

Thus,

$$-51.9 - 10 - 40 \log d2 = -82.4 - 40 \log d1$$
$$\log d2/d1 = 20.5/40$$

$$\underline{d1/d2 = 3.25}$$

This represents a definite problem, if the interfering mobile is 5 miles away from the fixed site, any interfering mobile within 1.5 miles will effectively block it. It would not be advisable to have a narrow band command channel in the main lobe of the spread spectrum. The amount of interference becomes one of statistics and the length of the interfering transmission. A mobile transmitting for a second would be harder to live with than one that transmitted for only a few milliseconds.

b) Assuming that the transmission from the fixed site B is situated in the sidelobe of the spread spectrum , then the effective interfering signal will be in the order of 30dB down on that given in a).

Hence,

$$-51.9 - 10 - 40 \log d2 = -112.4 - 40 \log d1$$
$$\log d2/d1 = 50.5/40$$

$$\underline{d2/d1 = 18.3}$$

If mobile B is, say, 5 miles from the fixed site, then interference will occur if any other unwanted vehicle transmit within a quarter of a mile of mobile B. This is more acceptable and therefore we can conclude that the command channel must be situated outside the main lobe of the spread spectrum.

c) Assuming that the transmission from the fixed site B is also a spread spectrum signal, then the effective interfering signal, Pr'' will be Pr' - PG.

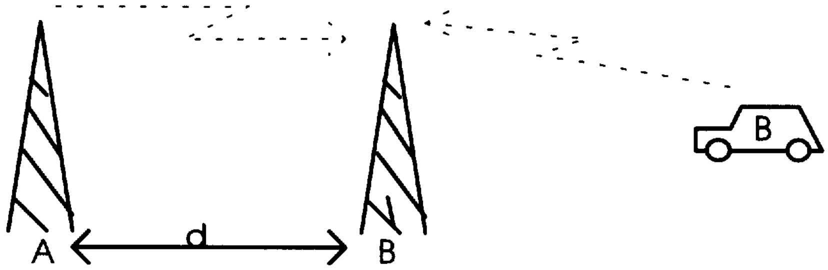
Hence,

$$-51.9 - 10 - 40 \log d2 = -60.4 - PG - 40 \log d1$$
$$\log d2/d1 = (-1.5 + PG)/40$$

PG = 15dB	= 24dB
<u>d2/d1 = 2.17</u>	<u>= 3.65</u>

These results represent a problem. A spread spectrum forward command channel could not be accommodated in a shared environment.

2.3. System A fixed site transmission blocking system B fixed site reception.



The propagation loss from the one fixed site to the other can be calculated using the 'free space' formula:

$Lp = 36.5 + 20 \log f + 20 \log d$ where f is frequency in MHz and d is distance in miles between the sites.

Assuming f = 920MHz $Lp = 95.8 + 20 \log d$

Assuming that the system A transmission is 500W, the received signal at site B is:

$Pr = 57 - 95.8 - 20 \log d$
$Pr = -38.5 - 20 \log d.$

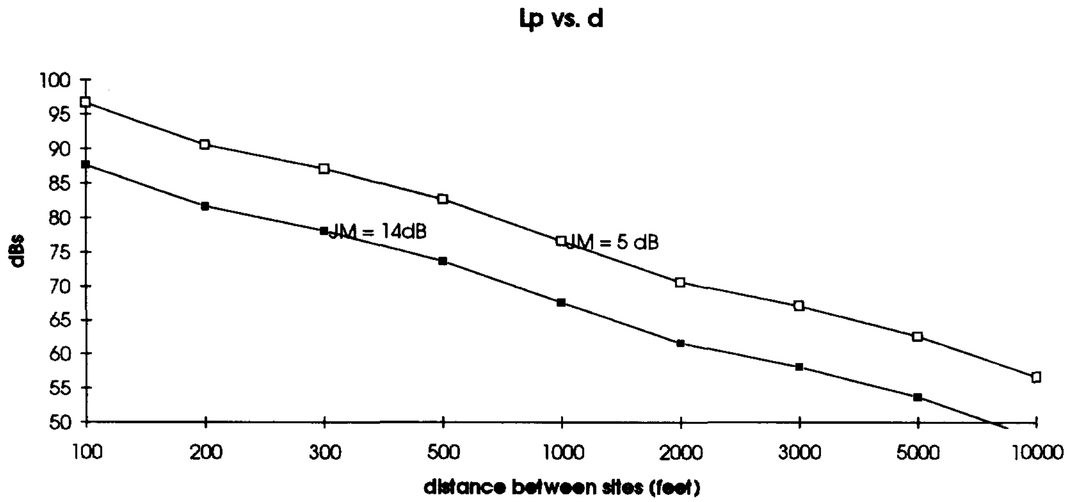
The theoretical noise floor, n ,at site B will be

$n = KTBN,$ where K is Boltzmann's constant,
T is the temperature,
B is the bandwidth
and N is the noise factor.

For a 4MHz bandwidth, and a 2dB noise figure,

$n = -106dBm$

The required filtering in order to attenuate the interfering signal so as to prevent desensitization can be calculated for various distances between the sites. The graph below gives the results for jamming margins of 5dB and 14dB.



From the above graph it can be seen that if the sites are close, which in practice means that they share the same antenna field, then filtering in the order of 90 to 100dB is required. This represents large, expensive filters. The further apart the sites the better, but the system designer would still need to assume the worst case[4].

From this result, it can be seen that the amount of filtering required is only practical if the frequency of the interfering signal is towards the outer edge of the allocated band. If the interfering signal was itself a spread spectrum signal, then no filtering is practical and complete blocking will occur.

2.4. System A fixed site transmission blocking system B mobile reception.

Assuming that the two systems do not share the same narrow band frequency, then this form of interference will not be a problem. If the interfering signal is spread spectrum, and the wanted signal narrow band, then the mobile will effectively attenuate the interfering signal by 22dB (assuming the

DECLARATION OF ANTHONY J. SPADAFORA AND GRAHAM K. SMITH

We, Anthony J. Spadafora and Graham K. Smith, are Vice President - Technology and Director - Systems Research, respectively, for METS, Inc., the general partner of MobileVision, L.P. We have prepared the foregoing technical annexes to the Reply Comments of MobileVision, L.P. in response to the comments filed in PR Docket No. 93-61, Amendment of Part 90 of the Commission's Rules to Adopt Regulations for Automatic Vehicle Monitoring Systems and we declare under penalty of perjury that the foregoing technical annexes to the best of our knowledge are true and correct.

Anthony J. Spadafora

July 29, 1993

Graham K. Smith

CERTIFICATE OF SERVICE

I, Rebecca S. Catelinet, hereby certify that copies of the foregoing Reply Comments of MobileVision were forwarded this 29th day of July 1993 by U.S. first-class mail to the following individuals:

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